

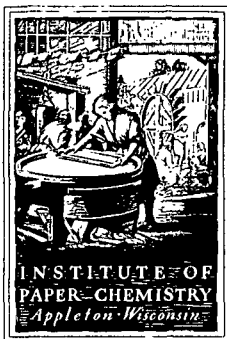
THE INSTITUTE OF PAPER CHEMISTRY, APPLETON, WISCONSIN

STATUS REPORTS

To The  
Engineering Project Advisory Committee

April 2-3, 1986  
The Institute of Paper Chemistry  
Continuing Education Center  
Appleton, Wisconsin

D. WAHREN



THE INSTITUTE OF PAPER CHEMISTRY

Post Office Box 1039  
Appleton, Wisconsin 54912  
Phone: 414/734-9251  
Telex: 469289

March 7, 1986

TO: Members of the Engineering Project Advisory Committee

Enclosed is advance reading material for the April 2-3 meeting of the Engineering Project Advisory Committee. Included are brief status reports for active projects, a revised agenda, and a current membership list.

Rooms have been reserved in the Continuing Education Center, and meals will be provided as stated on the agenda. If you haven't already indicated your attendance, please do so at your earliest convenience by calling Evonne Ludwig at 414/738-3320.

We look forward to meeting with you on April 2-3.

Sincerely,

Clyde H. Sprague, Director  
Engineering Division

CHS/el  
Enclosures

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\* \* \* TENTATIVE AGENDA \* \* \*

ENGINEERING  
PROJECT ADVISORY COMMITTEE

April 2-3, 1986

Continuing Education Center (CEC)  
The Institute of Paper Chemistry  
Appleton, Wisconsin

Wednesday, April 2, 1986

10:00am -- INTRODUCTION	Sprague/White
PROJECT REVIEWS	
- Fundamentals of Kraft Liquor Corrosivity	Crowe
- Fundamentals of Corrosion Control in Paper Mills	Yeske
12:00pm -- LUNCH	
1:00pm -- PROJECT REVIEWS - continued	
- Refining of Chemical Pulps for Improved Physical Properties	Farrington
- Process Fundamentals of Wet Pressing	Sprague
2:45pm -- BREAK	
3:00pm -- PROJECT REVIEWS - continued	
- Higher Consistency Processing	Farrington
- Fundamentals of Drying	Lavery
- High-yield Pulping	McDonough
5:30pm -- COCKTAILS	
6:00pm -- DINNER - CEC Dining Room	
7:15pm -- Quality Models in MAPPS Simulations	Parker

Thursday, April 3, 1986

7:15am -- BREAKFAST -- CEC Dining Room	
8:00am -- Discussion of Projects	Committee & Research Staff
9:30am -- BREAK	
9:45am -- Continued Discussion of Projects	
10:30am -- Report Preparation	Committee
11:30am -- Adjourn	
-- LUNCH - CEC Dining Room	

NOTE: The fall Engineering PAC meeting is scheduled for October 22-23, 1986.

ENGINEERING

Project Advisory Committee

Mr. David E. White (Chairman) 6/87\*  
Group Leader  
Research & Development  
Union Camp Corporation  
P. O. Box 3301  
Princeton, NJ 08542  
(609) 896-1200

Mr. LeRoy H. Busker - 6/88  
Director, Research & Planning  
Beloit Corporation  
Rockton R & D Center  
1165 Prairie Hill Road  
Rockton, IL 61072  
(608) 364-7961

Dr. Gerard P. Closset - 6/88  
Director, Papermaking and  
Coating Technology  
Champion International  
Technical Center  
West Nyack Road  
West Nyack, NY 10994  
(914) 578-7142

Mr. John W. Glomb - 6/88  
Corporate Research Director  
Research Department  
Westvaco Corporation  
299 Park Avenue  
New York, NY 10171  
(212) 688-5000

Dr. Sam Lin - 6/86  
Senior Process Engineer  
Owens-Illinois, Inc.  
One SeaGate  
Toledo, OH 43666  
(419) 247-5688

Mr. Max D. Moskal - 6/88  
Metallurgical Engineer  
Stone Container Corporation  
616 Executive Drive  
Willowbrook, IL 60521  
(312) 655-6949

Mr. Robert G. Murphy - 6/87  
Vice President, Pulp & Paper Technology  
James River Corporation  
P.O. Box 6000  
River Park 34A  
Norwalk, CT 06856  
(203) 854-2374

Mr. M. Thomas Neill - 6/88  
Technical Director  
Abitibi-Price, Inc.  
Research Centre  
Sheridan Park  
Mississauga, Ontario L5K 1A9  
CANADA  
(416) 822-4770

Mr. Amar Neogi - 6/87  
Senior Scientific Specialist  
Weyerhaeuser Company  
Tacoma, WA 98477  
(206) 924-6722

Mr. James Rugowski - 6/88  
Engineering Consultant  
Kimberly-Clark Corporation  
2100 Winchester Road  
Neenah, WI 54956  
(414) 721-2000

Mr. W. David South - 6/86  
Technical Director  
Chesapeake Corporation  
P. O. Box 311  
West Point, VA 23181  
(804) 843-5252

Mr. Ronald Swanson - 6/88  
Manager, Process Research  
Hammermill Paper Company  
P.O. Box 10050  
Erie, PA 16533  
(814) 456-8811

Dr. Donald Wensley - 6/86  
Engineering Associate  
MacMillan Bloedel  
3350 East Broadway  
Vancouver, British Columbia V5M 4E6  
CANADA  
(604) 254-5151

\*date of retirement  
4/2-3/86

THE INSTITUTE OF PAPER CHEMISTRY  
Appleton, Wisconsin

Status Report  
to the  
ENGINEERING PROJECT ADVISORY COMMITTEE

Project 3556  
FUNDAMENTALS OF KRAFT LIQUOR CORROSIVITY

February 21, 1986

## PROJECT SUMMARY FORM

DATE: February 21, 1986

PROJECT NO.: 3556 - Fundamentals of Kraft Liquor Corrosivity

PROJECT LEADER: D. C. Crowe

IPC GOAL:

Increase the useful life of equipment by proper selection of materials of construction and by identifying suitable process conditions.

OBJECTIVE:

To understand the causes of corrosion and corrosion-assisted cracking of carbon steels exposed to kraft liquor, as the basis for developing methods for reducing corrosion damage in kraft process streams.

CURRENT FISCAL BUDGET: \$130,000

SUMMARY OF RESULTS SINCE LAST REPORT: (October 1985 - February 1986)

Approach. Corrosion monitoring methods and equipment are being developed and demonstrated for use in kraft white liquor systems in mills. A better understanding of liquor conditions that accelerate corrosion is being developed in the laboratory as a basis for interpretation of behavior in real systems.

Previous Work. In previous work, the linear polarization resistance and electrical resistance techniques were evaluated for use in kraft white liquor. The electrical resistance technique gave good agreement with weight loss test results, and the linear polarization resistance method agreed well when a correction factor was applied. These methods were used in testing at four mills in white liquor tanks and clarifiers. The corrosion rate was found to vary significantly during the exposure, but this variability did not depend on liquor composition.

Previous laboratory results showed that corrosivity was increased by higher sulfide and caustic concentrations. Thiosulfate increased the corrosion rates dramatically. Polysulfide at moderate concentrations (<2.5 g/L) caused a short-term increase in corrosion rate. Liquor velocity also increased corrosion rates markedly.

#### Progress.

In this reporting period, a progress report entitled "In Mill Corrosion Monitoring in Kraft White Liquor" was published. The results from the first four mill visits were described. The corrosion rate was found to be dependent on white liquor composition; mills with higher sulfidity, causticity and thiosulfate concentration experienced higher corrosion rates. Liquor velocity was also a factor in mill corrosion. The four carbon steels used in the study were ranked in order of decreasing corrosion rate: 1018, A285C, A283, and A285 Special.

Two more mills were visited in this period and corrosion rates on white liquor clarifiers were successfully measured. The newly developed, microprocessor-based data acquisition system significantly improved our effectiveness and prevented the loss of data due to chart recorder failures. Improvements have been made to the system so that it will record electrical resistance readings in addition to the linear polarization resistance results. Similar systems may be useful to mills or their materials/research groups. The results from the two mill visits are being analyzed. One important results has been the observation of dramatic increases in corrosion rates when the liquor level was lowered below the electrodes and then raised. Glass seals used in the electrodes have been replaced with more dependable Conax fittings. Testing at another mill is in progress.



A second progress report, presented in the preliminary form at the last meeting and entitled "Liquor Composition Effects on Corrosion Rates in Kraft White Liquor", was published. Laboratory weight loss testing during this period indicated that additions of sulfite to white liquor did not increase the corrosion rate of 1018 steel. Thus, the presence of this species would not be expected to increase corrosion rates in white liquor systems. Weight loss testing has commenced to determine the effect of combinations of polysulfide and thiosulfate on corrosion rates.

A rotating electrode apparatus has been built and tested. There were minor problems with liquor leakage along the rotating shaft, but preliminary tests indicate that the redesign has successfully stopped the leakage. This apparatus will be used to obtain information on the effect of flow rate on corrosion. The corrosion rate at various shaft rotational speeds will be related to anticipated corrosion rates at specific liquor velocities in mill equipment. This information may be useful to designers in choosing pipe sizes and flow rates.

#### Plans for 1986.

1. Perform testing at more mills using the improved microprocessor-based data acquisition system and different electrode design.
2. Evaluate the effects of additions of combinations of polysulfide and thiosulfate to white liquor by weight loss testing in the laboratory.
3. Improve the rotating electrode apparatus and perform polarization tests and weight loss tests at various rotational speeds.
4. Perform slow strain rate tests in the laboratory using liquor collected from digesters.

Significance to the Industry

Modern corrosion measurement techniques and equipment have been developed and demonstrated for use in kraft liquor systems. Some operating parameters which increase corrosion rate have been identified. The effects of major liquor constituents on corrosivity of white liquor have been determined.

THE INSTITUTE OF PAPER CHEMISTRY  
Appleton, Wisconsin

Status Report  
to the  
ENGINEERING PROJECT ADVISORY COMMITTEE

Project 3309  
FUNDAMENTALS OF CORROSION CONTROL IN PAPER MILLS

February 24, 1986

## PROJECTS SUMMARY FORM

DATE: February 24, 1986

PROJECT NO.: 3309 - Fundamentals of Corrosion Control in Paper Mills

PROJECT LEADER: Ronald A. Yeske

IPC GOAL:

Increase the useful life of equipment by proper selection of materials of construction and by identifying suitable process conditions.

OBJECTIVE:

Improve the useful life of paper machine suction rolls by conducting corrosion and corrosion fatigue studies to establish the mechanisms of failure as the basis for developing approaches for prolonging roll life.

CURRENT FISCAL BUDGET: \$150,000

SUMMARY OF RESULTS SINCE LAST REPORT: (October, 1985 - February, 1986)

Approach. Current laboratory tests do not accurately predict the field performance of suction roll alloys, as measured by failure rate statistics. Alloys with impressive resistance in laboratory corrosion tests have not performed well in the field, compared to alloys with inferior results in laboratory tests. A better, more predictive test is needed to identify promising suction roll alloys and to develop new alloys in a more rational fashion.

Consequently, the current effort in this project is devoted to identifying one or more laboratory tests that correlate with performance of suction roll alloys in the field. Various corrosion-related tests are

being conducted on five suction roll materials whose service performance spans the range from good to poor. Those tests that discriminate between good and poor alloys will be examined for their relevance to cracking mechanism and subsequently used to develop and evaluate new alloys with greater promise of improved performance in suction roll applications.

Previous Work. A detailed report summarizing the current status of suction roll cracking has been distributed to the IPC member companies. The corrosion resistance of several suction roll alloys has been determined in corrosion tests conducted in simulated paper machine whitewaters containing chloride and thiosulfate species. A facility for investigating fatigue crack growth characteristics of suction roll alloys has been prepared and used to investigate the rates of crack growth in the near-threshold regime where crack growth is very slow. This facility has been used to determine the dependence of crack growth rates in Alloys 63 and 75 in several simulated paper machine whitewaters, under conditions representative of roll operation. No significant differences in crack growth behavior were previously found when comparing Alloys 63 and 75. Corrosion fatigue tests to examine fatigue crack initiation behavior in simulated whitewaters had been started. Slow strain rate tests to examine susceptibility of suction roll alloys to stress corrosion cracking were also inaugurated.

Progress. Early in the reporting period, a laboratory test was tentatively identified which correlated with the good and poor service performance of Alloys 75 and 63, respectively. The test involved measurement of the threshold cyclic stress intensity for fatigue crack growth in the regime where crack growth rates were very slow, during exposure to a simulated whitewater containing 1000 parts per million of chloride ion and a pH adjusted in the

range, 3.0 to 3.5. The cyclic stress intensity expresses the mechanical driving force for crack growth. A high threshold stress intensity for crack growth implies that cracks will not propagate unless a stress intensity exceeding the threshold value is applied. A resistant alloy will therefore have a high threshold stress intensity for crack growth, and a less resistant alloy will have a lower threshold stress intensity level.

In several simulated whitewaters and in air, the threshold stress intensities for crack growth were found to be about the same for Alloys 63 and 75 — two alloys at opposite ends of the spectrum of resistance to cracking in service. In these environments, the threshold stress intensity did not correlate with the resistance of these alloys to cracking in service.

However, in a simulated whitewater containing 1000 ppm  $\text{Cl}^-$  where the pH was adjusted down to the 3.0 - 3.5 range, Alloy 75 continued to show a high threshold stress intensity for crack growth whereas the threshold for Alloy 63 was much lower than in air tests. Furthermore, imposition of a mean tensile stress on the the Alloy 63 specimens during fatigue testing lowered the threshold still further, whereas the threshold stress intensity for Alloy 75 was unaffected by mean tensile stresses. The result is particularly meaningful since Alloy 63 is thought to carry high tensile residual stresses in service as a result of suction roll fabrication processes.

These results suggested that tests to determine stress intensity thresholds for fatigue crack growth in simulated whitewaters of relatively low pH may be a good predictor of suction roll performance in the field. In other words, differences in cracking resistance may be attributed to resistance to fatigue crack growth under conditions where cracks are short and driving forces for growth are relatively low.

Further tests were conducted to determine if the threshold stress intensity evaluation would accurately rank other suction roll alloys whose service history is known. Near-threshold fatigue tests were conducted in air and in the simulated whitewater described above using three additional suction roll alloys — VKA 171, VKA 378, and 3RE60. These tests were conducted with only a moderate mean tensile stress applied; tests with a high mean stress are currently underway. VKA 171 has experienced some cracking in service, but the VKA 378 has not (although few rolls of this composition are in service). The 3RE60 alloy has not experienced cracking in base metal, but some cracking was originally encountered in the welds of formed and welded rolls made from this alloy. Thus, the anticipated ranking for near threshold testing would have been:  $A75 = VKA\ 378 > 3RE60 > VKA\ 171 > A63$ .

The anticipated ranking was not found when the suction roll alloys were evaluated according to the threshold stress intensity criteria. The ranking based on threshold stress intensities in the low pH simulated whitewater was  $A75 > A171 = A378 > A63 \gg 3RE60$ . Differences between the threshold stress intensities for A75, VKA171, and VKA378 were not great, but Alloy 63 was clearly inferior to these three alloys. Furthermore, the 3RE60 material exhibited a very low threshold stress intensity — less than one-half the threshold exhibited by Alloy 75 tested under the same conditions. These results suggest that this near-threshold test is not entirely predictive of suction roll performance in the field.

A similar ranking for these alloys is found when the threshold stress intensities for crack growth in air are compared. The differences among the different alloys is not as that found in the simulated whitewater tests, however.

An unusual mode of crack growth would explain the low threshold stress intensities obtained with the 3RE60 alloy — the only wrought material tested thus far. Whereas the crack paths in the remaining cast alloys are torturous and branched, the crack path through the wrought 3RE60 alloy is straight and unbranched, reflecting the more homogeneous and more refined microstructure. Since torturous crack paths and crack branching both impede crack propagation by reducing the effective stress intensity at the crack tip, it is not surprising to learn that crack growth rates are high for the material that does not exhibit these deviations because of the uniformity of its microstructure.

Resistance to initiation of corrosion fatigue cracks in suction roll alloys is also being examined as a predictor of suction roll performance. Crack initiation is being studied by determining the number of cycles to failure,  $N$ , of smooth specimens subjected to alternating stresses of different magnitudes,  $S$ . A resistant material will require a high alternating stress to cause failure in 100 million cycles. Both alternating bending and rotating bending tests are being performed on the suction roll alloys described above. Tests are being conducted in air and in whitewaters containing dissolved thiosulfates and/or chlorides. In this reporting period, two additional rotating bending fatigue machines have been installed for corrosion fatigue testing.

No significant differences have yet been observed in the S-N behavior of Alloys 63 and 75 tested in a simulated whitewater containing 1000 ppm  $\text{Cl}^-$  and a pH adjusted to 3.0 - 3.5. For either alloy, the stress amplitude required for failure at 100 million stress cycles is approximately 25,000 psi. Tests have been started which examine corrosion fatigue resistance in a white-water containing ppm levels of thiosulfate and chloride.



Slow strain rate tests have been conducted on the five suction roll alloys to determine if stress corrosion cracking resistance predicts suction roll performance in the field. The test involves slow tensile tests of specimens of the alloy immersed in a simulated whitewater, followed by examination of the specimen and load-elongation records to identify evidence of cracking. The first series of tests has been completed in a simulated whitewater containing 500 ppm of thiosulfate and 100 ppm of chloride.

Of the five alloys tested, only Alloy 75 has exhibited any evidence of stress corrosion cracking in the form of severe pitting and secondary cracking. The other alloys do not show any evidence of degradation in this test. The implications of these results as a predictor of service performance remain unclear, since the only susceptible material has an unblemished record in the field.

Plans for the Next Period. In the next reporting period, the near-threshold fatigue crack growth testing will continue, using more aggressive simulated whitenwaters and higher tensile mean stresses. Corrosion fatigue testing to obtain S-N curves will also continue in an effort to identify a simulated whitewater where the resistance of Alloy 63 is inferior to that of Alloy 75. Slow strain rate testing will also continue in other simulated whitenwaters.

Repair welding practices will also be examined in the next reporting period for their effects on residual stress and corrosion resistance at the site of weld repairs.

Significance to the Industry. The search continues for a laboratory test that will predict the performance of candidate suction roll alloys in the field. Once this test is identified, it will be used to evaluate alternative alloys and in the development of new suction roll alloys with greater resistance to corrosion-assisted cracking.

THE INSTITUTE OF PAPER CHEMISTRY  
Appleton, Wisconsin

Status Report  
to the  
ENGINEERING PROJECT ADVISORY COMMITTEE

Project 3384  
REFINING OF CHEMICAL PULPS FOR IMPROVED PHYSICAL PROPERTIES

March 3, 1986

## PROJECT SUMMARY FORM

DATE: March 3, 1986

PROJECT NO. 3384 - Refining of Chemical Pulps for Improved Physical Properties

PROJECT LEADER: Ted Farrington

IPC GOAL: Develop ways to measure and control manufacturing processes.

OBJECTIVES:

1. To develop on-line techniques for measuring key process parameters controlling refiner performance with special emphasis on monitoring refining intensity.
2. To develop an understanding of relationships among fiber stock, refiner process variables (operational and design) and product physical properties which is sufficient to allow optimal control of the refining process.
3. Develop a refining model which can be used to predict the effect of refining and pulp variables on property development.

CURRENT FISCAL BUDGET: \$115,000

SUMMARY OF RESULTS SINCE LAST REPORT (October, 1985 - February, 1986)

Approach

In current practice low intensity may lead to good fiber development, but is very energy intensive. High intensity refining is more energy efficient, but may lead to increased fiber cutting and fines production. A better understanding of factors which influence stresses seen by individual fibers, and fiber response, would allow us to determine optimal operating stress levels. Such information could lead to improved refiner design and operation. When

coupled with an "intensity sensor", this knowledge would improve control of fiber development and energy utilization, especially in the case of more sensitive pulps.

### Progress

Preliminary tests with the instrumented Valley beater were discussed at the last review. Some correlation of sheet properties and normal force distribution was clearly indicated. Tangential forces proved insignificant in comparison to normal force data. Based on these observations, the major activity during the current period has been the execution of a statistically designed experiment to assess the usefulness of such force measurements and gain more basic information regarding effects of the refining process on both fiber and sheet properties. Only normal force data were collected during this work.

A four variable orthogonal rotatable design has been selected. Control variables are load, beater speed, consistency, and time. Table 1 documents the various experimental conditions. Times are spaced logarithmically based on previous results.

All beater runs are now complete and analysis has begun. Pulp samples of sufficient size (~1600 mL) for handsheets and several fiber tests were removed from each beater run at 2, 6.5, 20, and 35 minutes. Beater operating parameters and pressure data were collected at all times. Only those pulp samples corresponding to designed experiment points were made into handsheets and submitted for testing of sheet and fiber properties. All pulp samples have been retained for further analysis as indicated.

Considerable time and effort was expended in obtaining the pulp for this experiment. As one method to assess effects on fiber moisture transport

Table 1. Four-variable beater experiment design.

X1 = load (times standard)

X2 = consistency (%)

X3 = beater speed (rpm)

X4 = time (min)

Des. Exp. Point No.	X1	X2	X3	X4	Beater Run
1	3	2.5	575	20	A
2	3	2.5	575	2	
3	3	2.5	425	20	B
4	3	2.5	425	2	
5	3	1.5	575	20	C
6	3	1.5	575	2	
7	3	1.5	425	20	D
8	3	1.5	425	2	
9	2	2.5	575	20	E
10	2	2.5	575	2	
11	2	2.5	425	20	F
12	2	2.5	425	2	
13	2	1.5	575	2	G
14	2	1.5	575	2	
15	2	1.5	425	20	H
16	2	1.5	425	2	
17	3.5	2	500	6.5	I
18	1.5	2	500	6.5	J
19	2.5	3	500	6.5	K
20	2.5	1	500	6.5	L
21	2.5	2	650	6.5	M
22	2.5	2	350	6.5	N
23	2.5	2	500	60	P
24	2.5	2	500	1	
25	2.5	2	500	6.5	Q (repeat X5)

properties, it was decided to measure fiber pore size distribution during this work. As such, previously dried pulp was deemed inappropriate. The considerable efforts of personnel at Georgia Pacific's Bellingham, WA mill must be acknowledged. We now have a substantial supply of bleached sulfite softwood pulp which has never been above approximately 36% consistency. This "standard" never-dried pulp will serve to tie together future beater experiments and other investigations of moisture transport properties.

Beater operating data include torque, approximate resident time, and plate gap in addition to the control variables. Calculated parameters include refining intensity and specific edge load.

Handsheets have been produced and submitted for physical testing. Tensile, tear, burst, and density are measured by conventional means. Light scattering is employed as a measure of fines content. Both in-plane and z-direction moduli are determined ultrasonically.

Pulp not used for handsheets is used for fiber analysis and drainage tests. Britt jar tests are used to assess drainage behavior in addition to freeness testing. Fiber length distributions are determined using the Kajaani instrument. Fiber damage is assessed via SEM and staining techniques. Nitrogen absorption after solvent exchange is employed for intrafiber pore size distribution while mercury porosimetry is being tested as a means to assess layer inter-fiber pore structure.

ANOVA techniques and regression analysis are proceeding as data become available. A comprehensive report will be issued in late April.

Work is proceeding with the Beloit-Jones double disk refiner. Significant effort is being expended to accomplish the precise control of plate gap

necessary for anticipated research activities. This has required plate machining and the rebuilding of several components of the rotor assembly.

#### PLANS FOR 1986:

As only normal force data are now being collected, a piezoelectric transducer will replace the custom-made strain gage sensor currently used in beater trials.

At least one subsequent set of beater experiments will be performed with the current pulp. At least one other pulp will be investigated.

Work on the double disk refiner will continue and the beater sensor technology transferred when appropriate.

#### SIGNIFICANCE TO THE INDUSTRY:

Increased understanding of the factors which influence the stresses encountered by an individual fiber, and the fiber response, would assist us in maintaining stresses below levels which lead to undesirable fiber damage. Such knowledge may impact fiber refiner design and operation, as well as our ability to utilize cheaper but more sensitive pulps, such as hardwoods.



THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

Status Report

to the

ENGINEERING PROJECT ADVISORY COMMITTEE

Project 3480

PROCESS FUNDAMENTALS OF WET PRESSING

March 6, 1986

## PROJECTS SUMMARY FORM

DATE: March 10, 1986

PROJECT NO.: 3480 - Fundamentals of Wet Pressing

PROJECT LEADER: Open

IPC GOAL:

Fundamentally increase the potential capacity of processes.

OBJECTIVE:

To develop a model for the whole wet pressing process that can be used to predict water removal, density potential and other quality aspects.

CURRENT FISCAL BUDGET: \$140,000

SUMMARY OF RESULTS SINCE LAST REPORT: (October, 1985 - February, 1986)

Directed work on this project during the current reporting period has been limited by professional research staff constraints, but some progress has been made in two areas; displacement pressing and modeling of the conventional wet pressing project.

The effectiveness of displacement pressing in producing either high dryness or high bulk has been documented in previous reports. During the last period, a third generation displacement pressing head was developed and tests aimed at establishing engineering and economic feasibility were initiated. This new head embodied several improvements including provisions for measuring air driving pressure and flow through the sheet for calculation of displacement air energy requirements. A few data from this new head were presented at the last meeting.

Although the new head worked well in resolving most of the deficiencies of previous designs, water removal values were quite variable, even for a given set of test conditions. The cause of the scatter proved very illusive, only recently being traced to the outer holes in the lower drilled plate in the pressing "sandwich". These holes were allowing air to bypass the wet sheet at random locations around the periphery, depending on the alignment of the felt and the drilled plate. A temporary correction of this problem reduces the coefficient of variation of water removal to around 5% or less, a value considered acceptable for a multiple-step process such as this. A permanent correction will now be made and a carefully designed, comprehensive experiment conducted to assess the practicality of displacement pressing. This experiment will be completed to provide a definitive answer, but the initial results suggest that displacement pressing will be limited to a few applications.

Most of the work on the conventional wet pressing process has been motivated by the industry's continuing lack of a suitable predictive model, despite the scope and quality of the UMO work, and by the opportunity to capitalize on measurement techniques and model development in the impulse drying projects. Initially, the fine performance of the UMO laboratory press relative to pilot or real presses was attributed to the use of porous plates as water receivers. Earlier work in this project, now completed, has shown, however, that porous plates are actually inferior to felts. With this discovery, attention was turned to the segment of a wet pressing event not included in the UMO model; namely, unsaturated compression, constrained expansion, nip opening and post-nip contact. Limited work over this reporting period has been devoted to the development of instrumentation, experimental techniques and a modeling approach.

In previous pressing and drying work, various falling-weight and electrohydraulic press nip simulators have been developed. A sophisticated roll press, now being designed for impulse drying and pressing, will join this collection shortly.

For his PhD thesis work on modeling of impulse drying, Steve Burton has developed an instrumentation system for measuring the instantaneous density profile within a sheet during the drying period. This system is equally applicable to wet pressing and will be used extensively as a critical element in gathering data for the wet pressing model. It has now been shown that this same system may be extended to simultaneously track the density profile in the sheet and the density (compression) of the felt. Data gathered in this fashion will have obvious application in the modeling process, including identification of event boundaries (nip-opening, e.g.) and quantitative description of events.

Accurate measurement of hydraulic pressure during a wet pressing event has always been very difficult, but of central importance to modeling. Following the work of Beck (1) and Carlsson (2), we have worked out what appears to be a satisfactory hydraulic pressure measurement system.

Adhesion during the nip-opening process is important to overall wet pressing performance. As an aid to studying its contribution, special techniques have been worked out to eliminate or control adhesion between the wet sheet and the smooth platen. Some comparative data were shown at the last meeting.

With the generation of the measuring equipment and techniques noted above, data collection and modeling can begin. Attention will be focused first on the compression-expansion behavior of moist but unsaturated sheets to deve-

lop a structural model. This will be followed by consideration of always-saturated sheets to build network and fiber dewatering behavior into the model. Finally, the unsaturated states early in wet pressing and in the nip-opening and post-contact periods will be considered.

All of the experimental work for model building will be carried out on the various flat presses; the roll press will be used to verify/validate the model and test it for robustness. The intent is to develop a model to predict both water removal and density potential, given basic furnish and press design/operational data.

#### REFERENCES

1. Beck, D. A., Fluid pressures in a press nip: measurement and conclusions. Proceedings of the 1983 Tappi Engineering Conference, Book 2:475-487.
2. Carlsson, G., Some fundamental aspects of the wet pressing of paper. Doctoral dissertation. Stockholm, Sweden, Swedish Forest Products Research Laboratory, 1983.

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

Status Report

to the

ENGINEERING PROJECT ADVISORY COMMITTEE

Project 3479

HIGHER CONSISTENCY PROCESSING

March 3, 1986

## PROJECT SUMMARY FORM

DATE: March 3, 1986

PROJECT NO. 3479 - Higher Consistency Processing

PROJECT LEADER: Ted Farrington

IPC GOAL:

Reduction in complexity of forming systems.

OBJECTIVE:

To develop experimental and computational techniques necessary to better understand the behavior of fiber suspensions over a range of consistencies encompassing both current and potential future operations.

Ultimately to apply a better knowledge of fiber suspension micro-rheology to increase paper machine wet-end consistencies from current levels of 0.1-1.5% to 2.0-10%, depending on grade, without loss of machine speed or paper physical properties.

CURRENT FISCAL BUDGET: \$130,000

SUMMARY OF RESULTS SINCE LAST REPORT: (October, 1985 - February, 1986)

Approach

Previous work at IPC has focused on the development of high-consistency (HC) screening and separation processes. It now appears that the activities of others, especially Gullichsen, have resolved the major issues involved in HC processing up to the paper machine headbox. Also the HC separation process pursued at IPC has proven deficient in several aspects including separation

efficiency at HC conditions. For these reasons, our emphasis has shifted to HC forming processes.

Our investigation of forming processes comprises three activities which when considered together will eventually produce a more fundamental understanding of the controlling mechanisms while also allowing for early testing of promising HC forming concepts. These three activities are as follows:

1. An experimental investigation of the microrheology of concentrated fiber suspensions during high speed flows - Previous work at STFI during the 1970's and now in Japan have observed a loss in in-plane physical properties when attempting to form paper at HC conditions. The fundamental problem here is poor control of fiber (segment) orientation within the HC headbox and resulting sheet. Due to obvious difficulties involved, no one has investigated the fundamental behavior (microrheology) of fibers at high speed HC flows. This lack of understanding is responsible for the totally empirical nature of most previous attempts. Our basic strategy is to attack this problem from a more fundamental standpoint beginning with development of some technique to actually observe fiber orientation in the bulk during the process. Such a technique will give us a unique advantage which will allow us to either solve a HC forming problem from a fundamental approach or prove, based on fundamental information, why the problem cannot be solved.
2. Empirical testing of promising HC headbox designs - Our understanding of the problems involved in HC forming is largely secondhand and not based on direct experience. Also, there is some evidence that at least one HC execution does not result in severe loss of in-plane physical properties. To better understand the problems of HC forming and allow testing



of promising concepts in parallel with more fundamental studies, we are proceeding with several empirical HC former trials.

3. Computer simulation of turbulent fiber suspension flows - This activity is directed toward a better understanding of the development of fiber orientation and structure at lower consistency. Recent developments in computer technology and numerical techniques have produced the ability to dynamically simulate turbulent fluid flow in several simple geometries. These Large Eddy Simulation (LES) techniques display many of the qualitative and quantitative features observed experimentally in turbulent flow studies. Our objective is to apply this technique to the investigation of turbulent flow of dilute fiber suspensions. When successful, this will give us the first quantitative information regarding the relative importance of fiber-fluid and fiber-fiber interactions during these important flow situations.

In summary, our approach is to attack the HC forming problem with parallel efforts taking more fundamental and empirical approaches. In addition, we are investigating the complex behavior exhibited at even low consistencies during the turbulent flow of fiber suspensions. Our ultimate objective is to put the paper forming process (at all consistencies) on a more scientific basis via the application of new experimental and theoretical techniques.

### Progress

A significant portion of time since the last report has been devoted to finding an experimental technique capable of determining fiber orientation in the bulk of HC suspensions at high speeds (10 m/s). After considering a number of possibilities, it appears that high resolution/x-ray radiography offers the

best opportunity. Speed is not an issue as exposure times are typically under 100 nanoseconds. This technique depends on the use of some appropriate tracer fiber system of higher x-ray cross section relative to paper fibers and water.

Two flash systems were tested during the past period. A unique high resolution device under development at Lawrence Livermore Laboratories demonstrated the ability to resolve 7 micron tungsten filaments in air and 25 micron filaments through a thin section of HC pulp suspension. Exposure time was approximately 30 nanoseconds. A commercial device from Hewlett-Packard was also tested. Their 300 kV pulser can clearly resolve 25 micron metal filaments in a 1-cm example of HC stock. Again, exposure time was about 30 nanoseconds.

While very preliminary, we are encouraged by these results. This optimism is due largely to the extremely brief time spent at LLL and H-P to achieve useful results. Both resolution and penetration depth can be improved with optimization of the pulser/tube/tracer/film system. Recent information indicates that moderately high speed x-ray cineradiography may also be possible. The long-term key to success in this approach is the tracer. It must be imaged by x-rays but resemble paper fibers hydrodynamically and mechanically. Options such as lumen loading of paper fibers and coating of fine metal filaments must be investigated. When the system is developed we will have a unique technique for actually watching the development of fiber orientation during the high speed flow of HC suspensions.

While the LLL device can be constructed fairly inexpensively, the commercially available systems and potential systems for cineradiography may be quite expensive. As such, a significant portion of time during this past period has been devoted to preparing and finally submitting a proposal to the

Department of Energy for funding a fundamental study of concentrated fiber suspension microrheology. We anticipate response to this proposal during the next period (March, 1986 - October, 1986).

PLANS FOR 1986:

1. Construction of a flash x-ray device similar to that at LLL.
2. Documentation of system capabilities of the LLL device and application of it to several high speed flows of interest.
3. Empirical testing of at least two novel HC forming concepts on a laboratory scale.
4. Application of LES technique to turbulent suspension problem for at least one geometry.

SIGNIFICANCE TO THE INDUSTRY:

High consistency forming has the potential of reducing both capital and energy costs, and improving formation and physical properties control.

THE INSTITUTE OF PAPER CHEMISTRY  
Appleton, Wisconsin

Status Report  
to the  
ENGINEERING PROJECT ADVISORY COMMITTEE

Project 3470  
FUNDAMENTALS OF DRYING

March 3, 1986

## PROJECT SUMMARY FORM

DATE: March 3, 1986

PROJECT NO. 3470 - Fundamentals of Drying

PROJECT LEADER: Hugh P. Lavery

IPC GOAL:

Reduction of the "necessary minimum" complexity (number and/or sophistication) of process steps.

OBJECTIVE:

To bring the impulse drying process to the point of commercial development by achieving the following subobjectives:

- To experimentally define the energy efficiency and properties enhancement possible with impulse drying on a range of important grades.
- To design, build, and operate rolling nip pilot equipment to demonstrate the feasibility of the process.
- To calculate the mill-wide economic incentives for the most suitable grades and process systems.

CURRENT FISCAL BUDGET:

\$150,000 from Institute funds; \$350,000 from a Department of Energy grant (as Project 3595).

SUMMARY OF RESULTS SINCE LAST REPORT: (October, 1985 - February 1986)

Work on Project 3470 has been focused on impulse drying, with the objective of gathering data to support development of a commercial application of the process. Impulse drying may be defined as drying effected by the short-

time, high pressure and high temperature treatment of a previously pressed sheet. The high drying rates characteristic of impulse drying offer the potential for smaller dryer sections and improved energy use. Of at least equal interest is the potential for improved paper properties, property control, and substitution of lower cost furnishes at equal product strength.

Over the past six months, two major project branches have been active. First, with the support of the Department of Energy grant funds, a preliminary design for a pilot roll impulse dryer has been developed. The design is being reviewed with potential suppliers of the various pilot dryer systems and equipment costs are being developed. The pilot dryer will be fully instrumented for temperature, pressure, and heat flux measurement to permit careful studies of impulse drying performance in a realistic roll geometry. The equipment is being designed to test web samples up to 10 feet in length by 18 inches wide, to provide a reasonable demonstration of the process so that commercialization possibilities can be adequately evaluated. Continuous operation can be added in a later phase, if necessary. Priority has been placed in the design on providing for two-sided impulse drying so that this important process feature can be studied.

The second branch of the project activities involves continuing work on the bench-scale electrohydraulic press impulse dryer. A new phase of work has begun on this equipment, in which the results of the past year's technical performance evaluation experiments are being expanded in a few target areas. The principal new development on this equipment is the construction of a sheet preheating modification, which allows sheets to be impulse dried at initial sheet temperatures of up to 185°F instead of the room temperature sheets used in earlier work. The effects of preheating on water removal, energy efficiency,

and properties development are being evaluated. Work completed to date has concentrated on a high-yield chemimechanical pulp produced by the IPC Pulping Group; subsequent tests will study linerboard and newsprint. The water removal and energy efficiency response to preheating of the CMP samples has been very good. Between 1.5 and 2 times as much water is removed with presteaming when compared with cold sheets under otherwise constant conditions. The energy efficiency (Btu/lb water removed) is improved by a similar factor. Physical properties effects are being evaluated and should be available by the time of the meeting.

Additional physical property data from the past year's technical performance evaluation work has been acquired over the past six months. The results show that impulse dried linerboard sheets retain their strength advantage relative to conventional sheets when conditioned at high humidity, but that the decline in strength with humidity follows a line parallel to that for conventional sheets. Impulse drying thus does not fundamentally change the response of sheets to high humidity. A further study of impulse drying of linerboard under constant PLI conditions has shown that of the two PLI components (nip width and peak pressure), the nip width or residence time is the more important variable in water removal and density development. A further study on sheet densification in linerboard under impulse drying, static pressing, and roll pressing conditions has shown that the densification and properties relationships all lie along the same lines. Impulse drying thus represents a continuation of trends familiar to papermakers and not completely unknown territory. Additional data from these studies should be available by meeting time.

Student research related to Project 3470 includes Steve Burton's study of the dynamics of the densification processes in impulse drying, which is due

for completion by June, 1986, and a Master's project by Harry Dundore on the mechanisms of strength development in CMP under impulse drying conditions which has just been initiated.